That is to say, the greater the precipitation on the land the larger the evaporation from it, unless the increase in run-off equals the increase in the precipitation, which we know in general it does not. This, however, does not prove that the precipitation is to any extent increased by the land evaporation—though there are good reasons for thinking that it is. If it does not increase land precipitation it must then increase ocean precipitation, for total evaporation from land and ocean must equal total world precipitation. But, as implied, it is preactically certain that, owing to vertical convection caused by surface heating and by mountain ranges, land evaporation increases land precipitation more than ocean precipitation.

(3) *For a restricted area—a given watershed, say.*—

Let V_i = amount of vapor brought by winds to the given region in a year.

V_e = amount of vapor carried by winds from the given region in a year.

p_1 = amount of precipitation from vapor V_i on the given region in a year.

p_2 = amount of precipitation from evaporation over the given region in a year.

$P = p_1 + p_2$, or total precipitation on the given region in a year.

R_s = surface run-off from the given region in a year.

R_u = underground run-off from the given region in a year.

$R = R_s + R_u$, or total run-off from the given region in a year.

E = evaporation from the given region in a year.

Then $V_i - V_o = R_s + R_u < p_1$, because some of the local precipitation is supplied by local evaporation, as in heat thunderstorms, for instance; $P - (R_s + R_u) = E > p_2$, since some of p_1 also is evaporated. These seem to be the only useful equations available between the terms given. In a closed basin where $R = 0$, $E = P$; in an open basin, $E = P - R$. Some measurements indicate that at places P may be several fold R. Say, $P = AR$, then $E = (A-1)R$. But P and R_s are measurable, and often the value of R_u can be approximated—seldom more, perhaps, than 1 per cent of R_s. Hence, a more or less accurate value of E is determinable.

In regard to a restricted area we can only say that the evaporation is a result of the precipitation—we can not say to what extent the local precipitation is a result of local evaporation.

It is obvious, however, that evaporation from vegetation and from the soil often is very great—the temperature of the air frequently is high (many degrees higher than over the ocean at the same latitude), the tree foliage is well up in the atmosphere, and finally the air is well mixed—more so than over the ocean. For all these reasons—high temperature, elevation of evaporation surfaces, and mixing of air—it seem certain that, when moist, land evaporation must be great and free. It is also obvious that this evaporation must increase leeward precipitation, but to what extent does not at present seem determinable.

That local evaporation increases leeward precipitation seems to be the logical explanation, at least in part, of, among other things, the facts (*a*) that "all signs fail in dry weather"; (*b*) that "during wet weather it can rain without half trying"; and (*c*) that in the case of a rapid succession of rain storms passing over a semiarid region, each penetrates farther than its predecessor. Professor Henry has called my attention to examples of (*c*) on the Pacific coast of the United States.

PRECIPITATION, EVAPORATION, AND RUN-OFF

By W. J. HUMPHREYS

Dr. C. E. P. Brooks's timely and admirably conservative paper on the influence of forests on rainfall and run-off[1] appears to offer a possible means of determining relations between precipitation, evaporation, and run-off that after all may not be as reliable as it seems. This is not a criticism of his fine contribution to an intricate subject, but rather a reminder of an inherent difficulty that no one yet has managed to solve.

Let all quantity symbols refer to the average amount per second. Let P be the total precipitation per second, as specified, over the land; R, the run-off; and E, the evaporation; then

$$P = R + E$$

Some of E is reprecipitated on the land—call it P'; and some, x, is not. Hence

$$P = R + P' + x \tag{1}$$

and

$$P - P' = R + x$$

If V_{op} is the amount of on-shore vapor that is precipitated onto the land and V_o the amount of on-shore vapor that is not so precipitated; and, finally, if the total amount of water vapor coming to the land from the ocean is n times the amount leaving the land, then

$$V_{op} = R + x$$

$$V_o + V_{op} = n\ (V_o + x)$$

and

$$x = \frac{R}{n-1} - V_o$$

If n is 2, a reasonable assumption suggested by Brooks,

$$x = R - V_o;$$

but we have no means by which to determine V_o, hence x also is unknown. Brooks appears to assume that V_o is negligible and thus gets the relation

$$x = R.$$

On substituting this value of x in (1), it would seem that the precipitation on the land due to evaporation from the land is equal to the *total* precipitation thereon less twice the run-off; or, in symbols, that

$$P' = P - 2R.$$

Actually, though,

$$P' = P - \frac{n}{n-1}R + V_o$$

But, as stated above, V_o is unknown; therefore P' also is unknown. And the more significant the value of V_o the less reliable any estimate we may make of P'.

[1] *Q. Jr. Roy. Meteorol. Soc.*, 54, 1, 1928.